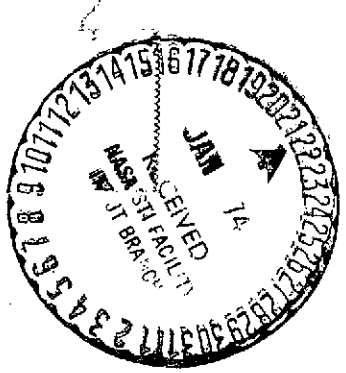
EFFECT OF ACQUISITION LEVEL ON INCREASED PARADOXICAL SLEEP DURATION DUE TO AVOIDANCE CONDITIONING IN THE RAT

Elisabeth Hennevin, M. M. Pierre Leconte and Vincent Bloch

Translation of: "Effet du niveau d'acquisition sur l'augmentation de la durée du sommeil paradoxal consécutive à un conditionnement d'évitement chez le Rat," Comptes Rendus, Academie des Sciences, Serie D, Vol. 273, 1971, pp. 2595-8.



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EFFECT OF ACQUISITION LEVEL ON INCREASED PARADOXICAL SLEEP DURATION DUE TO AVOIDANCE CONDITIONING IN THE RAT

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ABSTRACT

The increase in the duration of paradoxical sleep after learning augments with the order of sessions up to the platform of the learning task where it stops. After each session the increase in paradoxical sleep is manifested only for 30 minutes after falling asleep.

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INTRODUCTION

Under the hypothesis that paradoxical sleep (PS) plays a part in the stabilization mechanisms of the memory trace, it has been shown that learning (labyrinth [1], avoidance conditioning [2]) was followed by a significant increase in the duration of paradoxical sleep. In a previous publication [2] avoidance conditioning was done in a 90-minute session (70 tests) after which the electrocorticograms and electromyograms of the animals were recorded for 4 hours. The increase in PS was not shown beyond a period of 3 hours after learning.

However the "massed" learning technique used did not enable us to find out whether the increase in PS was connected to consolidation of the learning completed or to the acquistion activity itself. In this study we used the same conditioning, but with a "distributive" learning technique to establish a relationship between the stages of acquisition and the paradoxical sleep periods following them. In addition, to examine the progress in time of this PS increase, we analyzed our recording by shorter units of time.

*Numbers in the margin indicate pagination in the foreign text.

MATERIALS AND METHODS

We used 20 rats weighing about 200 gms into which cortical (fronto-parietal branching) and myographic (hooks attached in the muchal muscles) electrodes had been inserted.

The experimental group (n = 12) is trained in alternating avoidance conditioning in a two-compartment cage. The conditioning stimulus is a 1000 Hz sound transmitted for 2 seconds and preceding an electric shock on the floor of the animal's compartment.

The control group (n = 8) is placed in a similar cage; it receives the same number of sound and electric stimuli as the experimental group but these stimuli are not connected by temporal conditioning laws.

PROCEDURE

For a pre-experimental period of 2 days, in their individual cages, the animals are connected to the recording apparatus to accustom them to wearing wires.

Then the electrocorticographic (ECoG) and electromyographic (EMG) traces are taken for 2 days in succession for 3 hours at a time, at a time in the day which, for each animal, is the same throughout the experiment. The slow sleep (SS) and paradoxical sleep (PS) phases are identified from ECoG and EMG criteria; the total durations of SS and PS phases are measured for each period of recording. The averages of the 2-day duration are the reference values for the duration of SS (SS_o), the duration of PS (PS_o) and the duration of PS as a ratio of total sleep (PS_o/TS_o). /2596

In the following days the experimental animals (group E) underwent a daily session of 15 avoidance conditioning tests for 15 minutes. The control animals (group C) are placed under the conditions described above during these 15 minutes.

Immediately afterwards, the animals in both groups are put back in their cages and recorded for 3 hours, always at the same time of day. We continued with conditioning until we reached the "platform" (the differences between the performance in the third and fourth session was not significant).

RESULTS

The following table summarizes the results obtained in 3 hours recording before any treatment (control recording, column 0) and those for the conditioning days.

TABLE I

		0	1	2	3	4
SS in sec	E	4949	4767	4665	4505	5454
	C	5196	4922	4885	5442	5216
PS in sec	E	672	**813**	**887**	**1047**	703
	C	731	521	690	567	724
PS/TS in %	E	11.59	**13.67**	**15.35**	**18.76**	10.96
	C	11.15	9.16	11.70	9.28	11.51

Column 0: control values (before treatment)

Columns 1, 2, 3, and 4: Conditioning sessions (group E) and pseudo-conditioning sessions (group C). The values differing significantly from those in column 0 are printed in bold type.

For all sessions and for both groups of animals there was no significant variation in either the duration of total sleep (SS + PS) nor latency of falling asleep.

The amount of paradoxical sleep was practically invariable in the control animals (no difference was significant). On the other hand, in the experimental animals with respect to the reference amount we observed, up to day 3, a progressive increase in the amount of PS related to the degree of conditioning: this

increase was significant on the first day of conditioning at $P<.10$, on the second day at $P<.02$, on the third day at $P<.001$. On day 4 the amount of PS is similar to that with the control recording.

The experimental group has no modification in the duration of slow sleep. As shown in Fig. 1 the variations in the amount of PS are hence due only to variations in the duration of PS. As with the amount, the greatest increase in duration is on day 3 of conditioning ($P<.01$) and on day 4 this duration once more becomes identical to that observed with the control recording. //2598

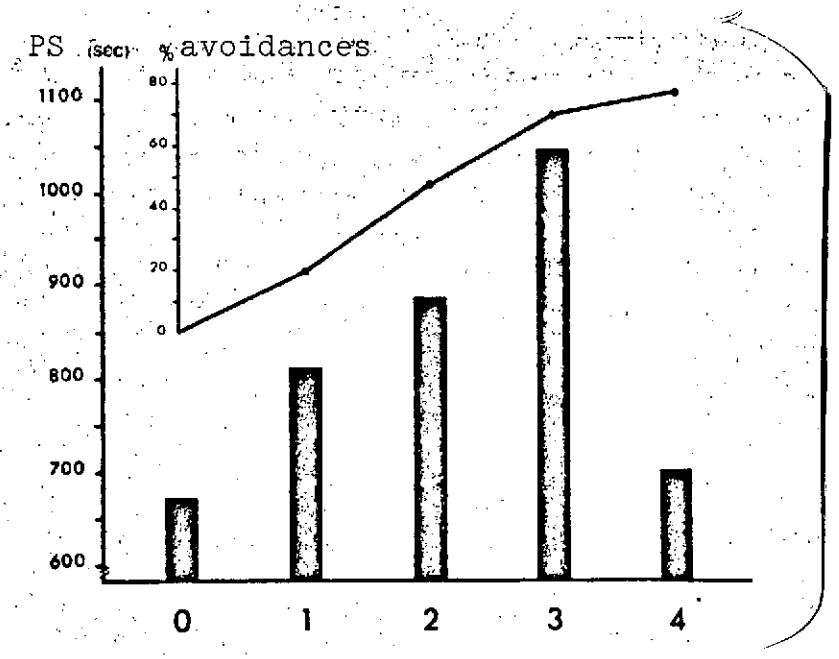

Fig. 1. Variations in PS duration in group E animals for 3 hours after each daily conditioning session. The value 0 is the duration of PS before any treatment. The values 1, 2, 3, and 4 correspond to the order of the learning sessions. Above the histograms is the learning curve (for this curve the Y axis represents the percentage of conditioned avoidances).

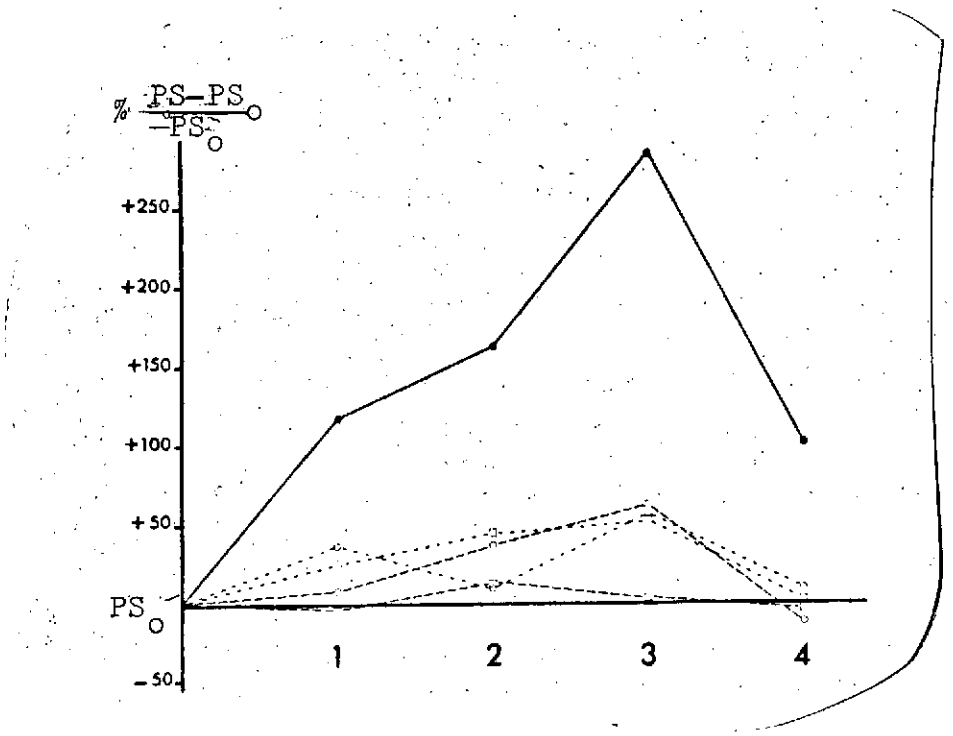

Fig. 2. Study in group E of relative variations for each half hour of sleep of the duration of PS with respect to duration of PS before any treatment (PS_O), on the four days of conditioning (solid line: variations in PS duration during the first half hour of sleep).

Moreover this increase in the total duration of paradoxical sleep is not connected to an increase in the average duration of each phase but to an increase in the number of phases, this being particularly clear on the third day of conditioning ($P<0.001$).

In order to analyze the progress in time of these modifications in paradoxical sleep we studied the recordings each half hour. Fig. 2 shows the relative variations in the durations of PS for the first, second, third, fourth, and fifth half hours of recording after the animals had fallen asleep, this being about 25 minutes after the learning session. One hour after the session we observed no further significant modifications in the duration of paradoxical sleep, and the PS increases are manifested almost solely during

the first half hour of sleep. In particular, on the third day of conditioning the duration of PS, in this first half hour of sleep, is 3 times greater than the same half hour of the control recording ($P<0.01$).

DISCUSSION

As we showed in a preceding publication [2] avoidance conditioning is followed by a significant increase in paradoxical sleep. We have seen here that this increase is characterized by an increase in the number of PS phases and by a lengthening of the average duration of each phase.

This phenomenon depends on the level of conditioning acquisition; to each stage of conditioning corresponds an increase in PS over the previous stage until the platform is reached. Indeed, it is on the third day of conditioning that the increase in paradoxical sleep is most substantial and, on the fourth day, when the platform of the learning curve is reached we no longer observe any modification in PS as compared to the control. It does seem that if we are entitled to state that PS is needed for memory fixation, this need increases with each stage of conditioning and disappears when learning is established. The need for PS thus seems to be manifested essentially in the conditioning establishment phase. It looks as though we are dealing with a process that becomes more intense with each stage in the progression of learning and stops when learning is completed. Moreover, the analysis of result half hour by half hour shows that the increase in PS occurs essentially when the animal falls asleep for about half an hour: this phenomenon thus seems to be immediate and brief in nature.

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